IAEA – RER1020 Project
To enhance and consolidate regional capability in on-line industrial process diagnosis, optimization and troubleshooting, using radiotracers and sealed source techniques

ME – RER1020 – 1801741
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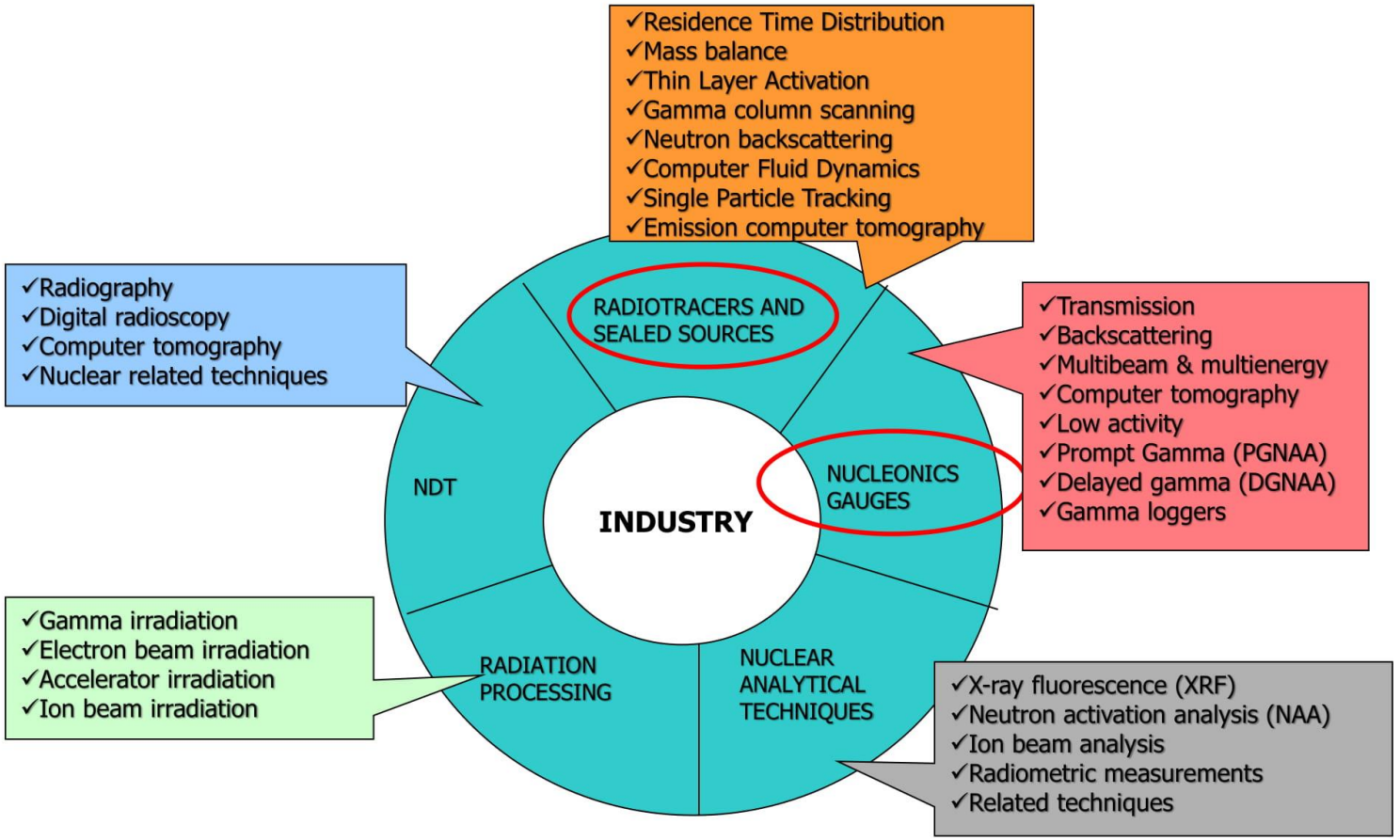
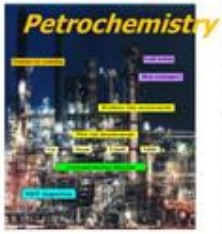
APPLICATIONS OF RADIOTRACER AND RADIOISOTOPE TECHNIQUES IN INDUSTRY



What is industry ?

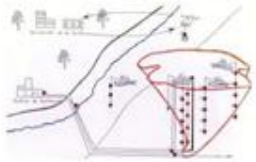
Industrial processes



Irrigation

sediment transport

Dams



Outfalls

Mechanics

Pollutant release and aquifer protection

Dredging

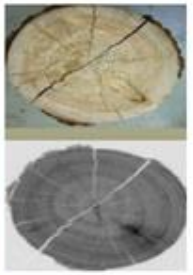
Ore processing

Mining

Cement

Wood

Oil fields

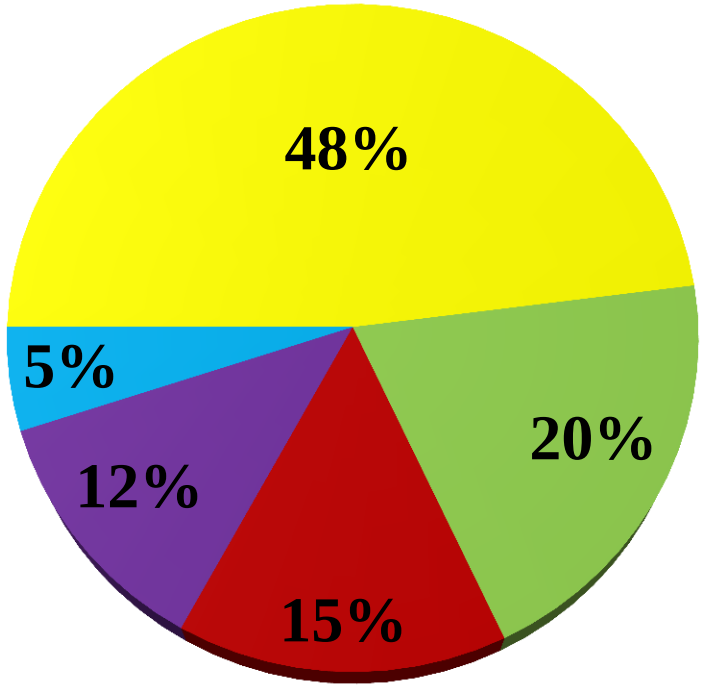


Major radiotracer and sealed source techniques

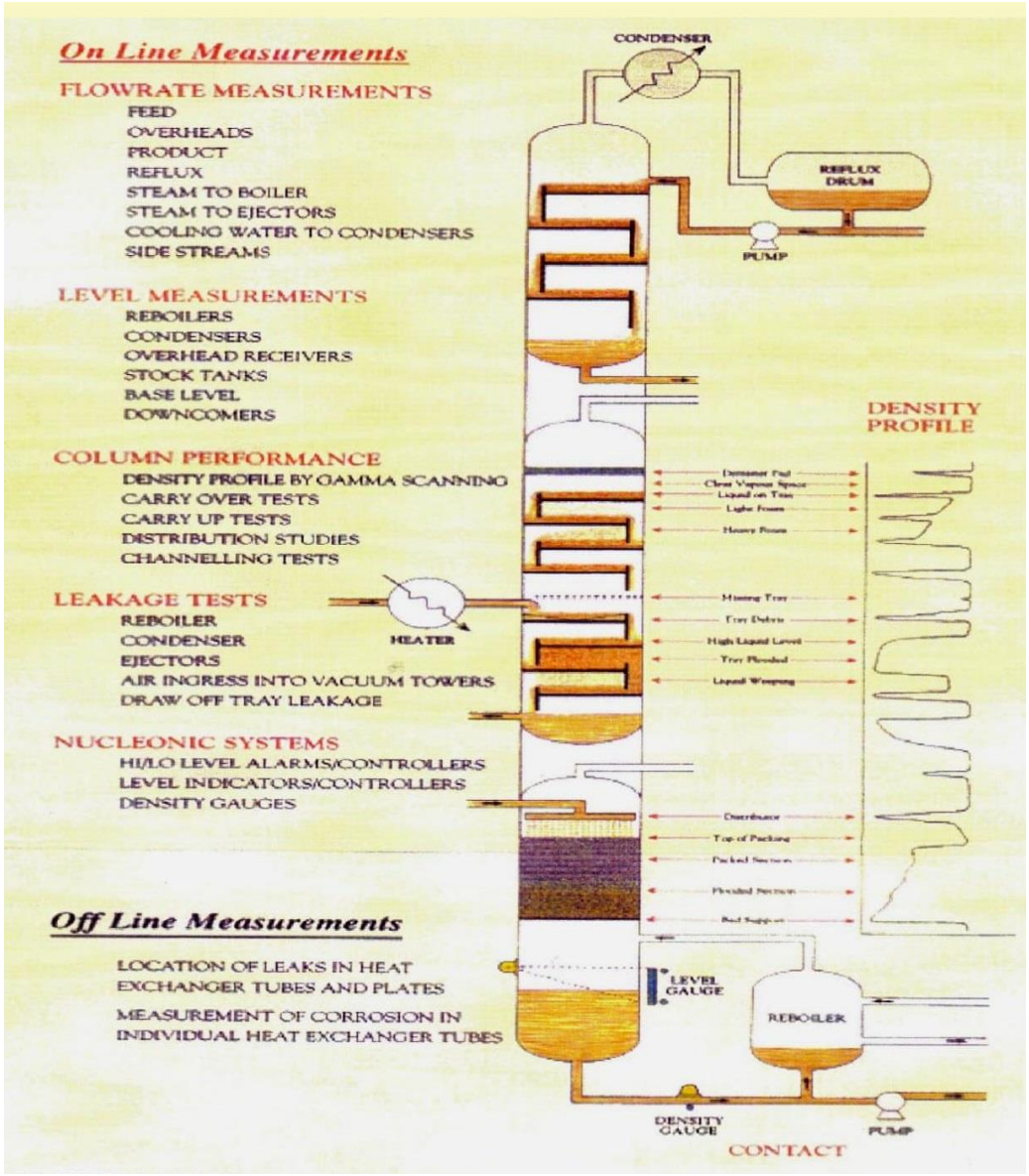
Major mature radioisotope techniques applied in routine services to industry are:

- Radiotracer residence time distribution (RTD) for troubleshooting and analysis
- Radioisotope gamma scanning for columns and pipes troubleshooting inspection
- Neutron backscattering for level and interface detection
- Radiotracers for leak detection in heat exchangers
- Radiotracers for flow rate measurement of liquid and gas fluids in pipes
- Radiotracer for interwell tracer test (IWTT) investigation in oil fields

Major radiotracer and sealed source techniques used in industry for troubleshooting and optimizing industrial processes



Potential of radioisotopes for troubleshooting inspection and control of processing columns



RTD applications

Major targets

Petroleum industry

Oil refineries are one of the main users, and beneficiaries of the technology. **Fluidized catalytic cracking unit (FCCU)** upgrades 'heavy' components of oil to gasoline. Technically, this is also the most complex unit, involving interaction of multiple phases: solid catalyst, vaporized feedstock steam and air. Because of construction and extreme operating conditions of FCCUs, only effective way to diagnose them are radiotracers.

Enhancing oil production in oil fields. Main radiotracer technique is the measuring of the 'time of travel' between injection and production wells. If a water injection is to be effective in sweeping out oil from the permeable zones it is important to ensure that short-circuiting or channeling, whereby much of the residual oil may be bypassed, does not occur. Therefore, it is important to understand how the water from injection well travels to the producer. Tritium as tritiated water is ideal tracer for water.

Petrochemical complexes

Petrochemicals plant lies immediately downstream of oil refinery and in many developing countries construction of two types of facility is proceeding in parallel.

Like refineries, petrochemicals plants are generally continuously operating and technically complex. Thus, high economic benefits may be realized by applications of radiotracer techniques on petrochemicals units.

Diagnosis of cracking furnace, primary fractionator and gas separation chain is of the highest potential value.

Cement and minerals processing

Cement and minerals processing plants, in one form or another are to be found in practically every country in the world and in many cases they are major contributors to national economies. There are certain processes found throughout the cement and mineral processing industries:

- Grinding
- Classification
- Flotation
- Homogenization

Objectives of radiotracer investigations:

- Troubleshooting
- Process control and optimization
- Investigation of flow patterns
- Investigation of design and scale-up studies
- Development verification mathematical models

Benefits: Proper hydrodynamics is a key to improve the process.

Hydraulic detention times in wastewater treatment ponds

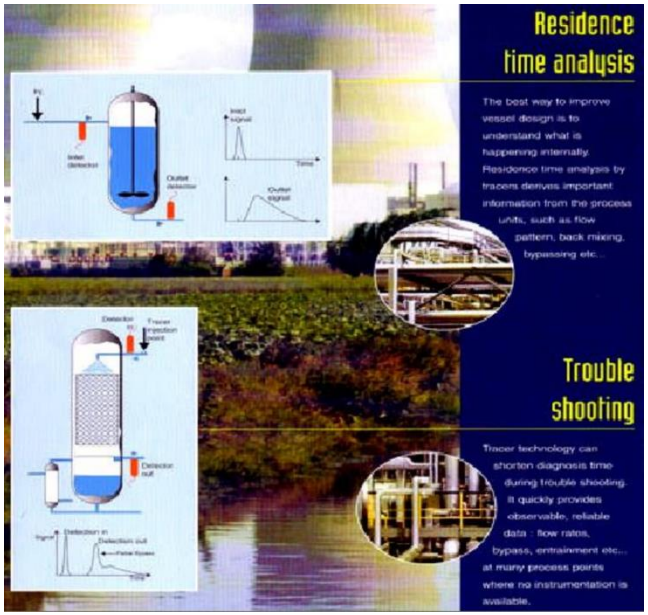
- Primary justification is based upon health and environmental considerations, rather than purely on economic benefit per se
- Modelling by RTD aids both design and performance optimization of wastewater treatment systems
- Operation of a wastewater treatment lagoon can be deceptively complex. Given unsatisfactory state of current theoretical approaches, there is a need to be able to assess performance practically
- Water gamma tracers such as $Na^{131}I$, ^{51}Cr-(EDTA) and ^{113m}In-(EDTA), or $^{113}InCl_3$ for tracing solid phase can be used depending on the size of the pond when in situ measurement extends over hours, days or even weeks

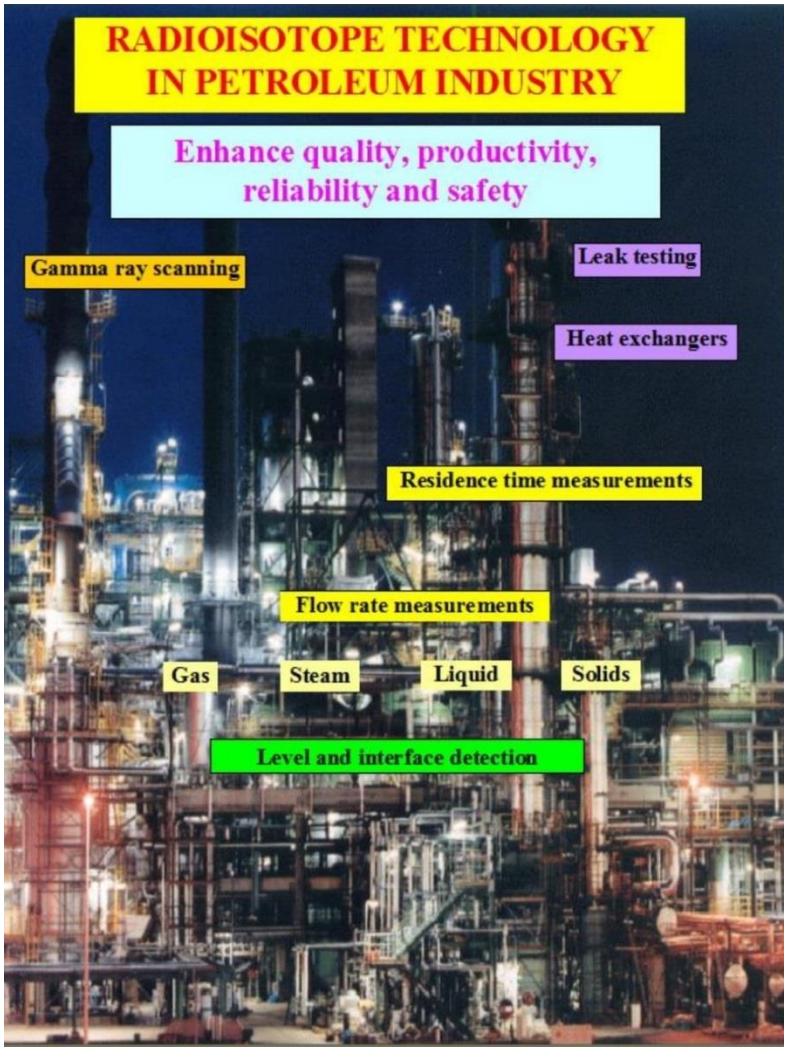
The benefits are:

- **Ensuring thorough treatment of wastewater thereby safeguarding the environment**
- **Operating existing ponds more effectively-saving money, providing data for the design of future ponds**

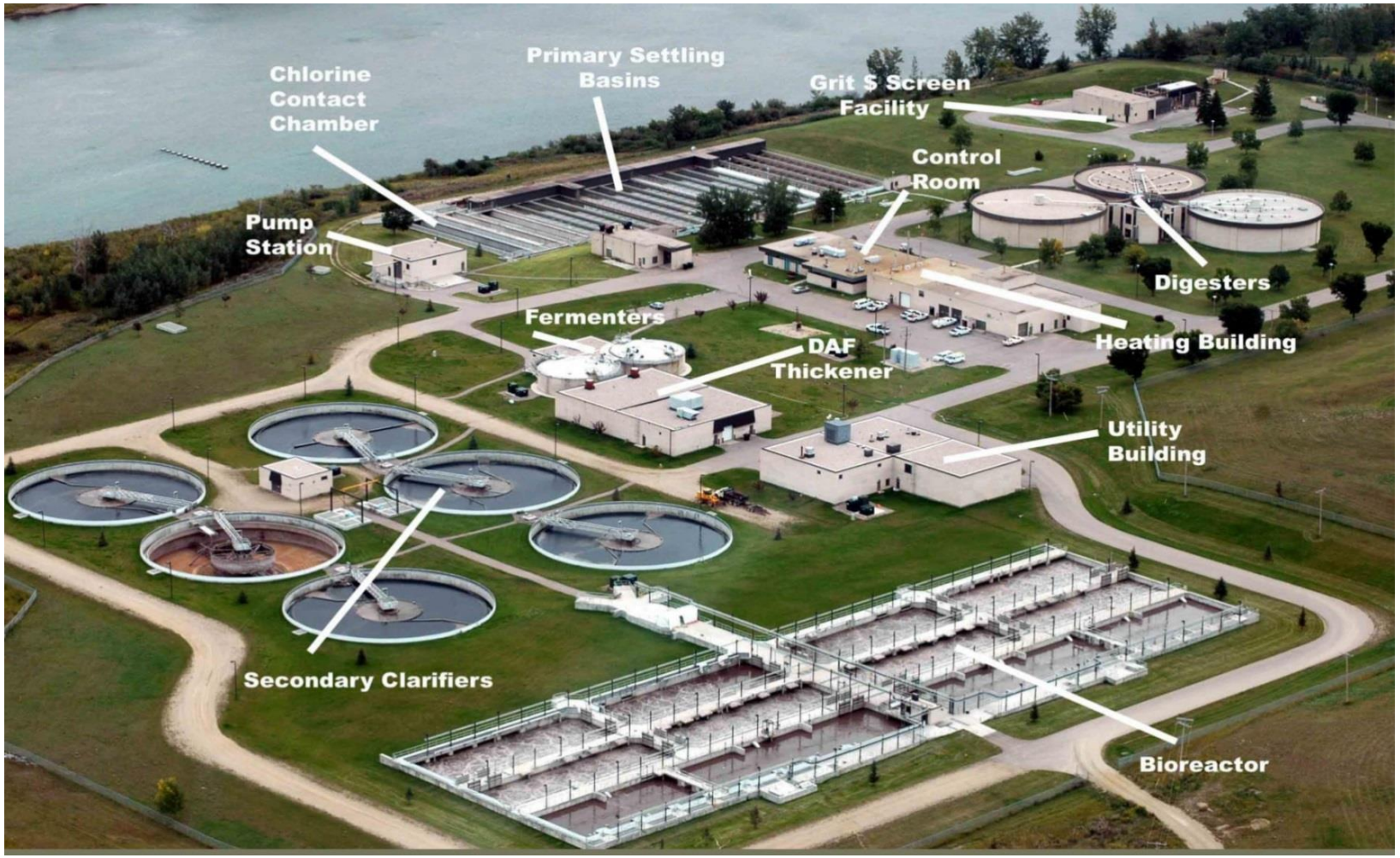
Radioisotope technology in petroleum industry

- Enhance quality, productivity, reliability and safety
- Improve efficiency
- Reduce production down-time
- Make worker's performance easier
- Reduce industrial pollution
- Save money



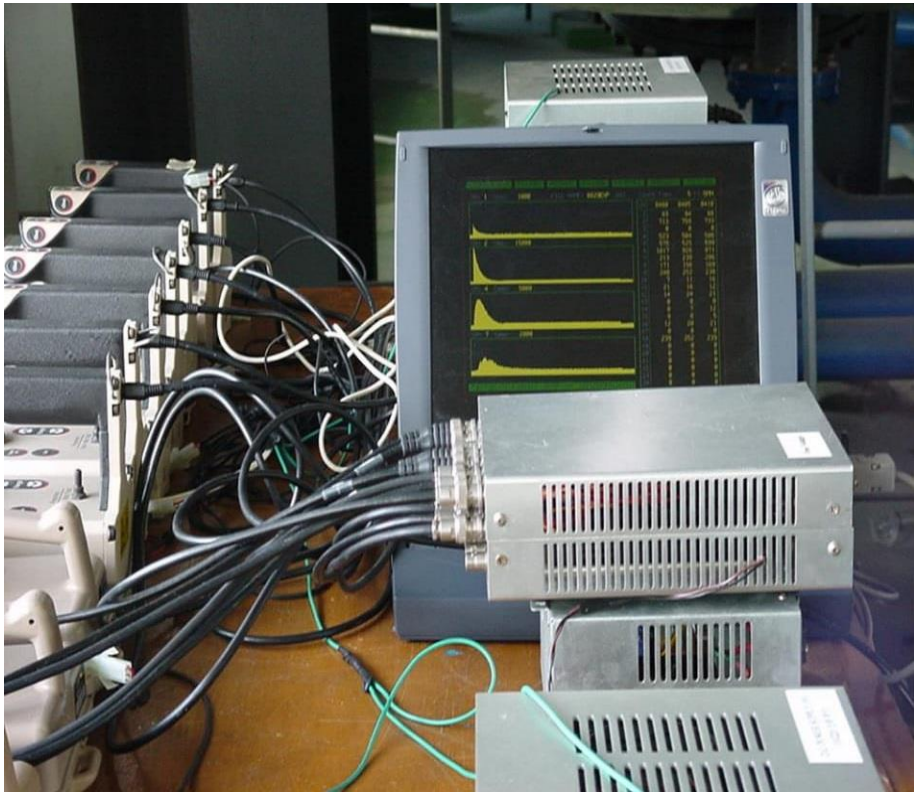


Radiotracers for efficient management of wastewater treatment plants (WWTP)



RTD measurement

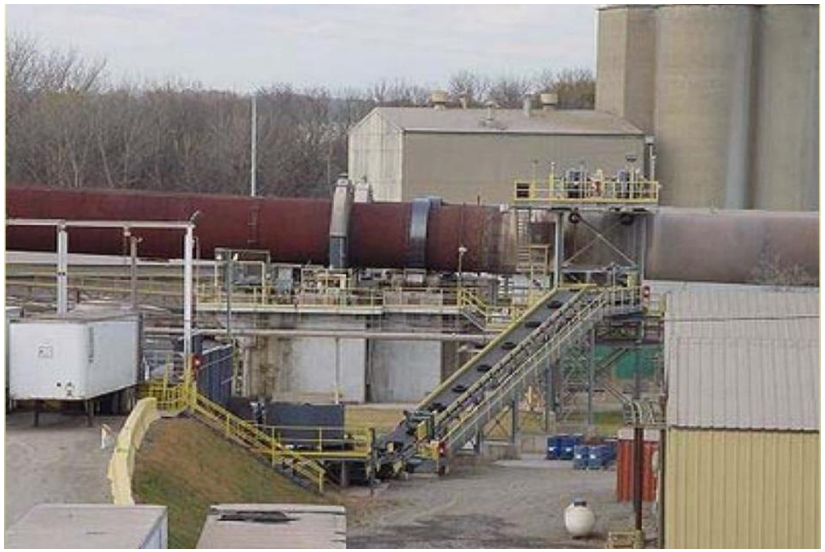
Data acquisition system connected with many probes

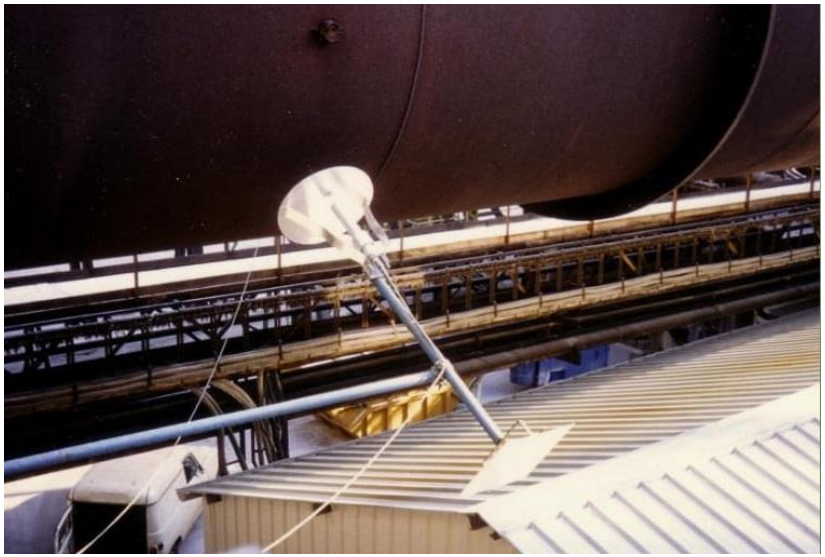


Radiotracer test in wastewater treatment plant

Rotary kiln

Feed entering the back end of the kiln, flows countercurrent to the movement of the hot gases passing through the chain section and finally emerging as hot clinkers at front end.





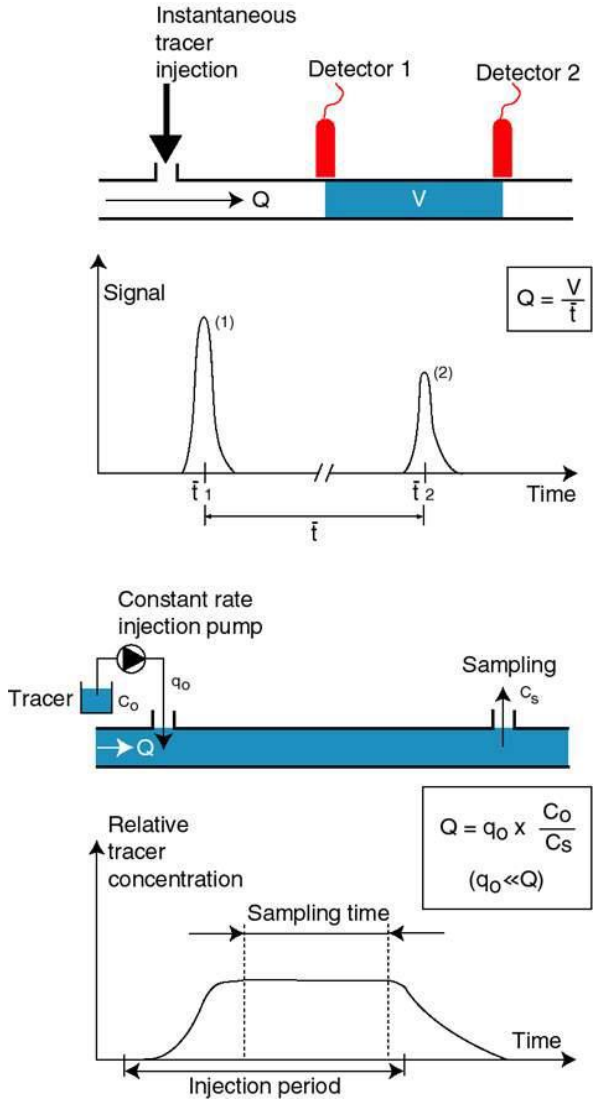
Clinker grinding mill

Grinding systems are either ‘open circuit’ or ‘ closed circuit’. In an open circuit system, the feed rate of incoming clinker is adjusted to achieve the desired fineness of the product. In a closed circuit system, coarse particles are separated from the finer product and returned for further grinding.

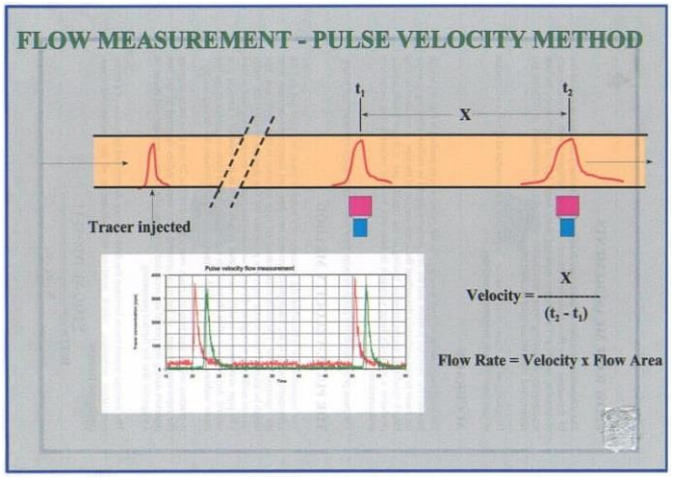
Radiotracer techniques for flow rate measurement

The two methods available for flow measurement are pulse transit time, which gives velocity directly and the dilution method which gives mass flow rate directly.

Measurement procedures are based on the application of the ISO norms (4093 for gas and 2975 for liquid). Better than 1-2% accuracy is achievable.



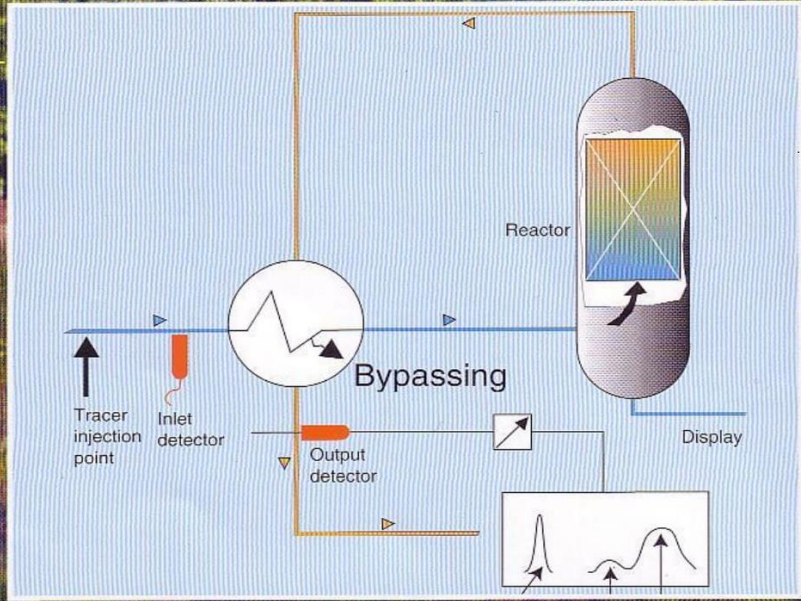
Flow rate measurement in Thailand



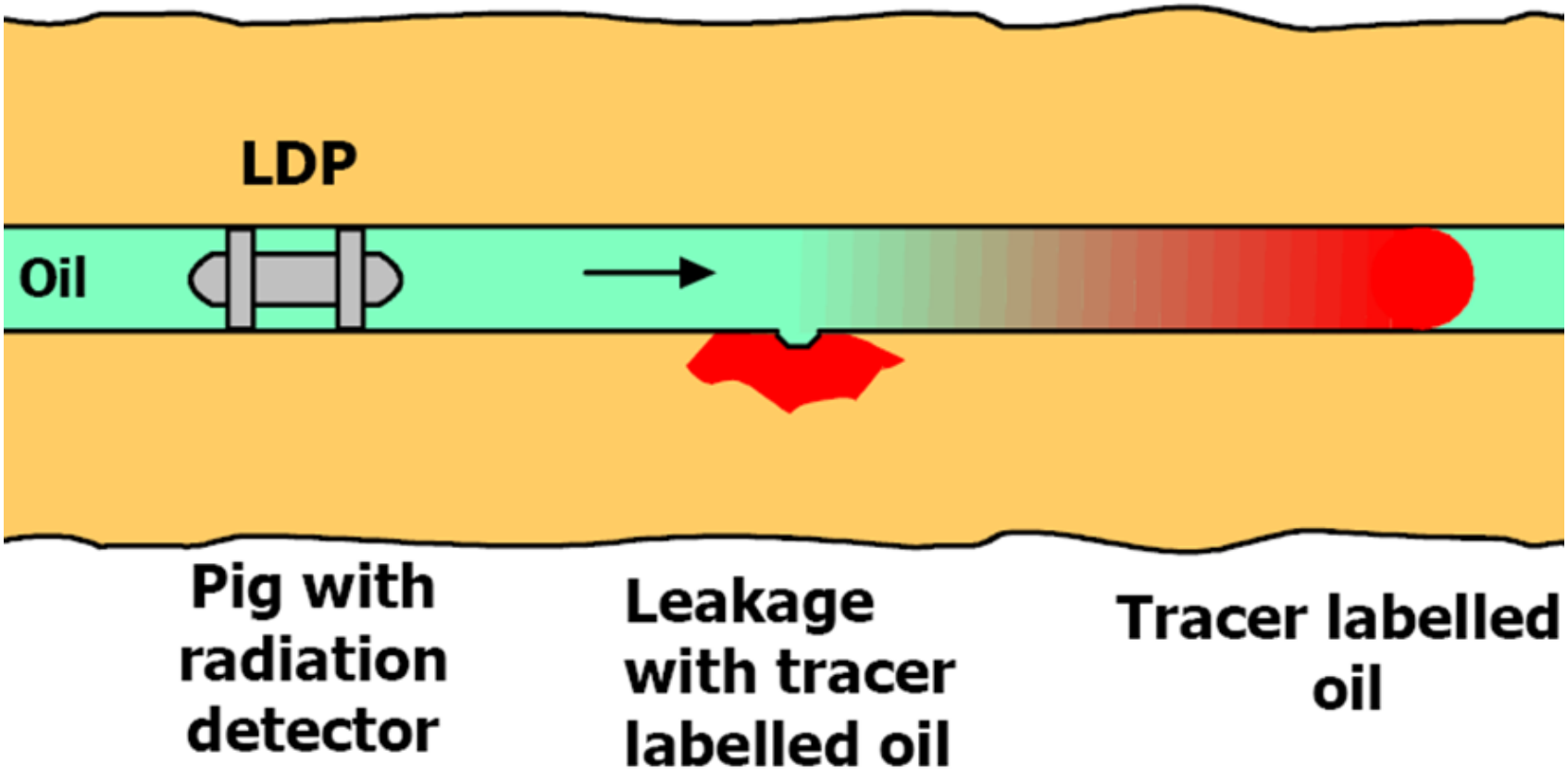
Radiotracer technique for leak detection in heat exchangers

Leak detection

Difficult to locate, internal process leaks often cause serious problems... Tracer techniques offer an effective response to this problem. Typical detection threshold is between 1% and 0.1%, but lower levels are obtainable in some cases.

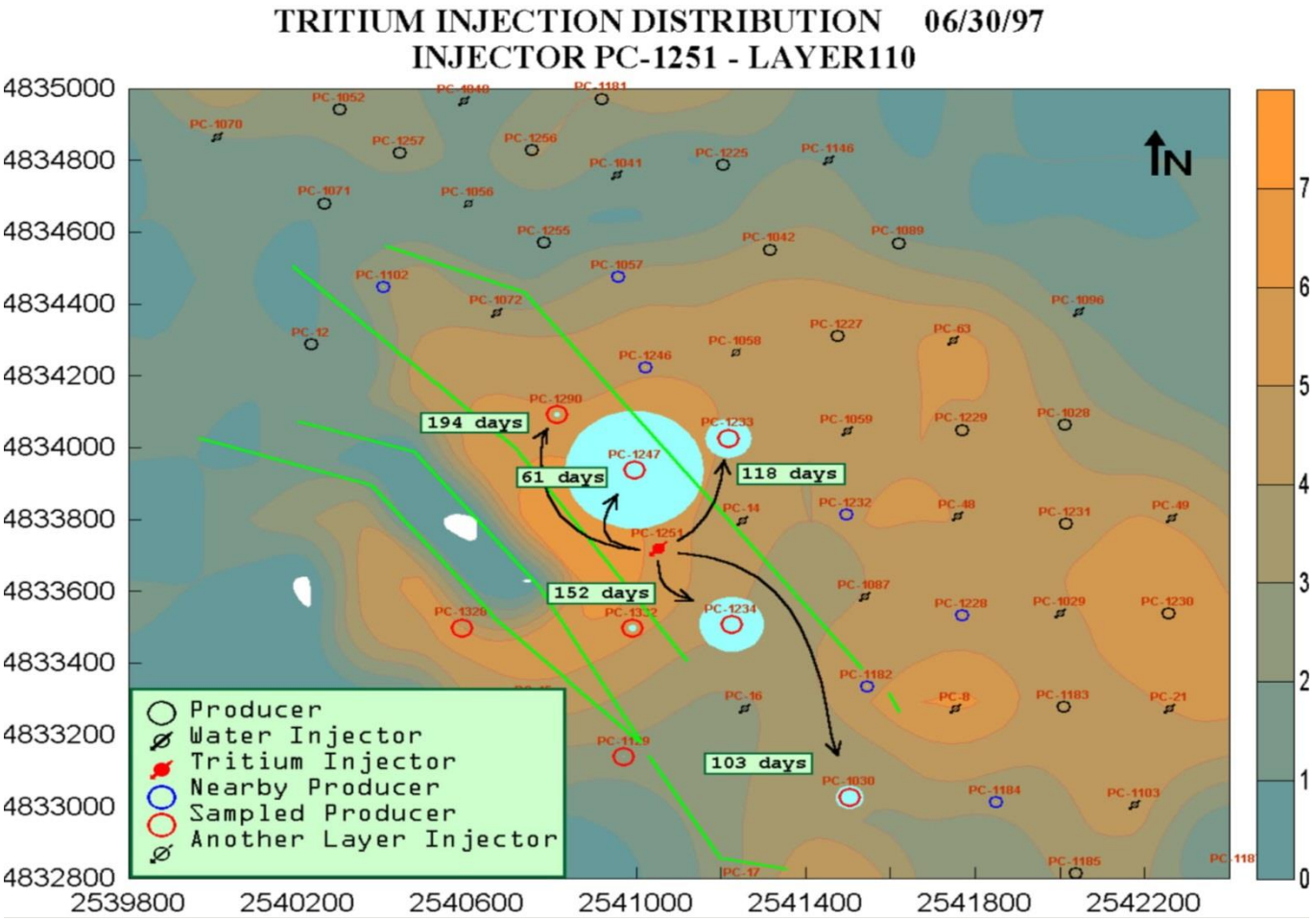


Detection of leaks in underground pipelines (> 1 m)

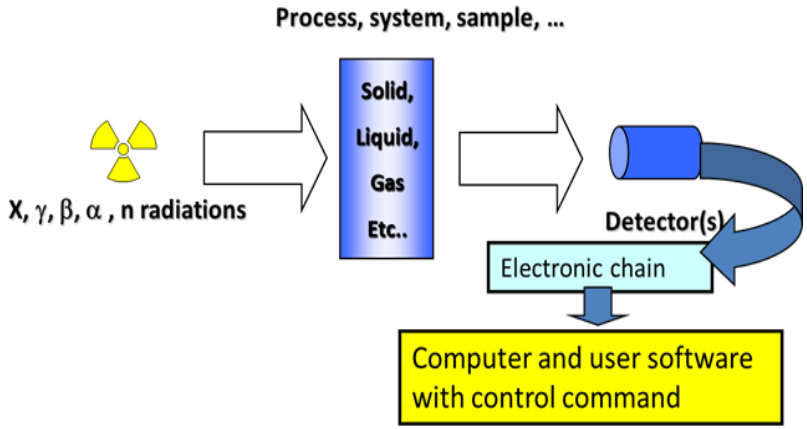


Polish leak detection 'Pig' demonstrated in Libya in an IAEA activity some years ago

Radiotracers for interwell studies in oil and geothermal fields



Application of nucleonic control systems (NCS)



Scheme of nucleonic control system (nucleonic gauge)

- On-line process (NCS): density, thickness, level, concentration, elemental analysis
- Off-line process (bulk sampling): coal and mineral processing
- In situ (well logging): mining for coal and minerals
- Used in laboratory (on samples): elemental analysis, coal ash, moisture
- Portable, for site measurements: thickness, blockage, corrosion, density, moisture, etc.

Prompt gamma neutron activation analysis (PGNAA) using radioisotope neutron sources of ^{252}Cf or ^{241}Am-Be is largely applied for on-line coal ash, mineral slurry and cement raw material analysis in modern industry. The PGNAA cross-belt analyser is a precise on-line multielemental analyser for bulk materials. The PGNAA is recently used for borehole logging as well.

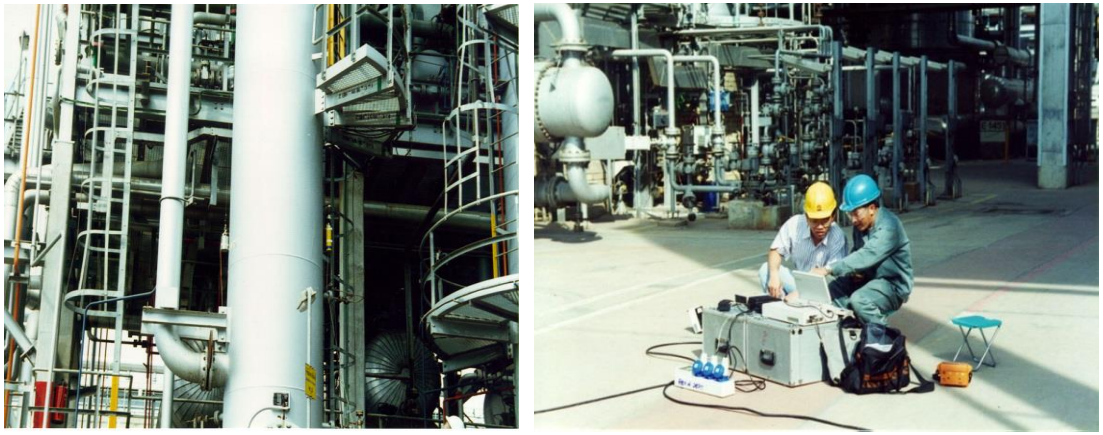
PGNAA method used for borehole logging in copper mining

Some examples of nucleonic measurement and control systems

Paper Thickness *Mineral Industry* *Coating*

Application of sealed sources

Gamma scanning is the best technique to carry out an internal inspection of any process equipment, without interrupting production. A collimated beam of penetrating gamma rays is allowed to pass through the shell of a vessel, gets modified by the vessel internals and then coms out of the other side. By measuring the intensity of the transmitted radiation, valuable information can be obtained about the densities of the materials present inside the vessel. The higher the density of the material, the less radiation gets through; so significantly more gamma rays are transmitted through a vapour compared to a liquid phase.



Performing gamma scanning of distillation column in petroleum refinery

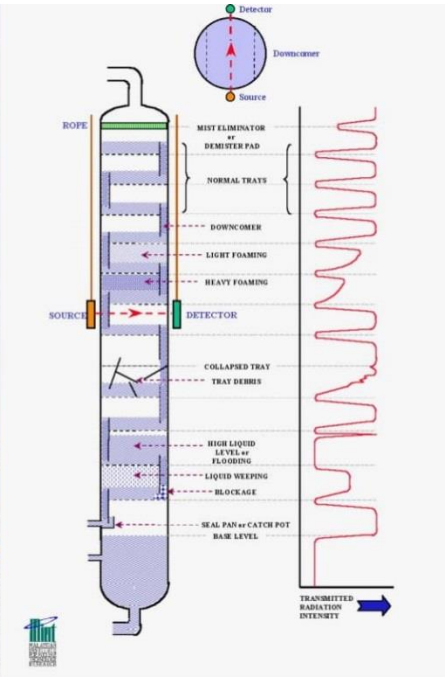
Density scanning of distillation columns is the most commonly used application of this technique. Without affecting processing unit, this reliable and accurate technique can be used to determine:

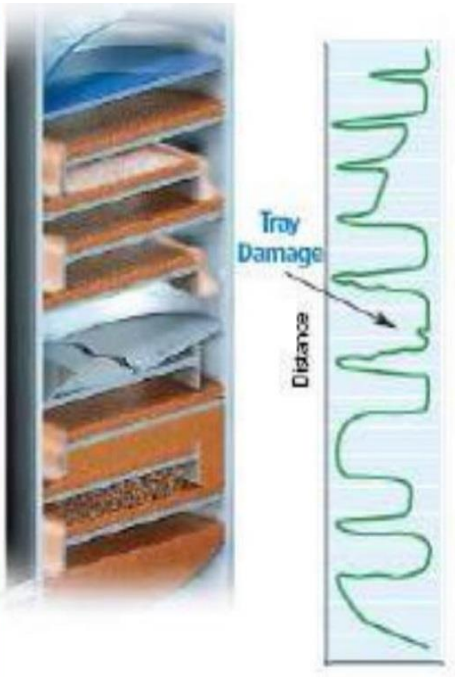
- The liquid level on trays
- The presence or absence of internals, such as trays, demister pads, packing and distributors
- The extent and position of jet and liquid stack flooding
- The position, and the density characteristics of foaming

The scanning of pipelines for blockages or build-up is another excellent use of gamma scanning because it is faster and uses lower radiation levels than conventional X-ray techniques.

Gamma scanning

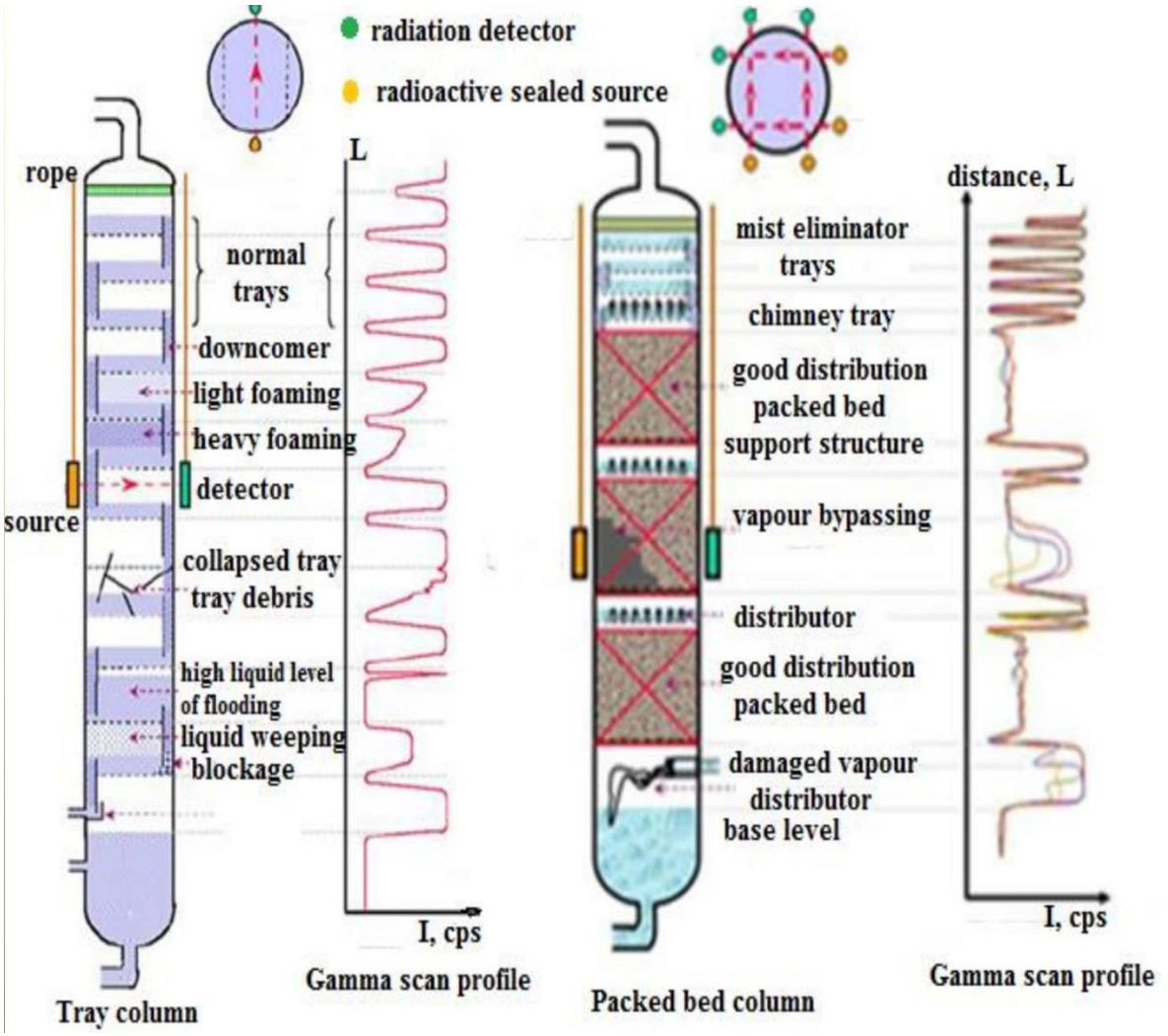
Gamma scanning provides the clearest picture of on-line conditions inside a process vessel. For one column: cost 5000-7000 — benefit 100,000-150,000 US$ (CBR = 1:20)



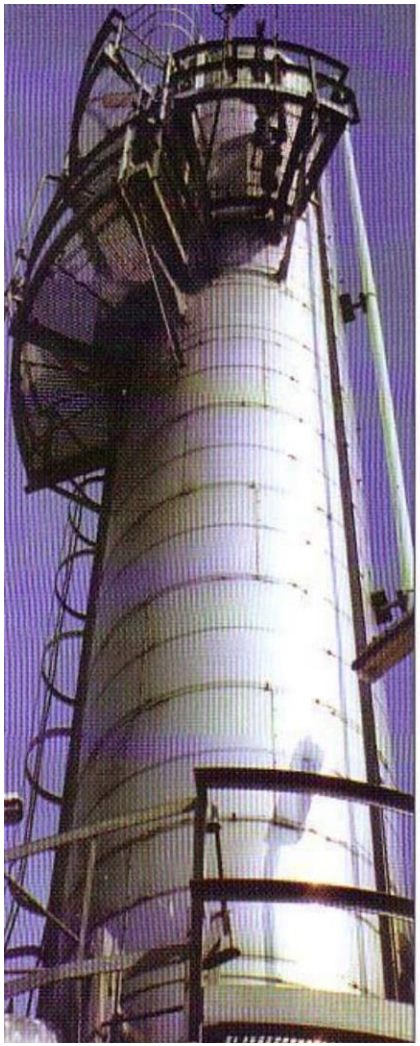


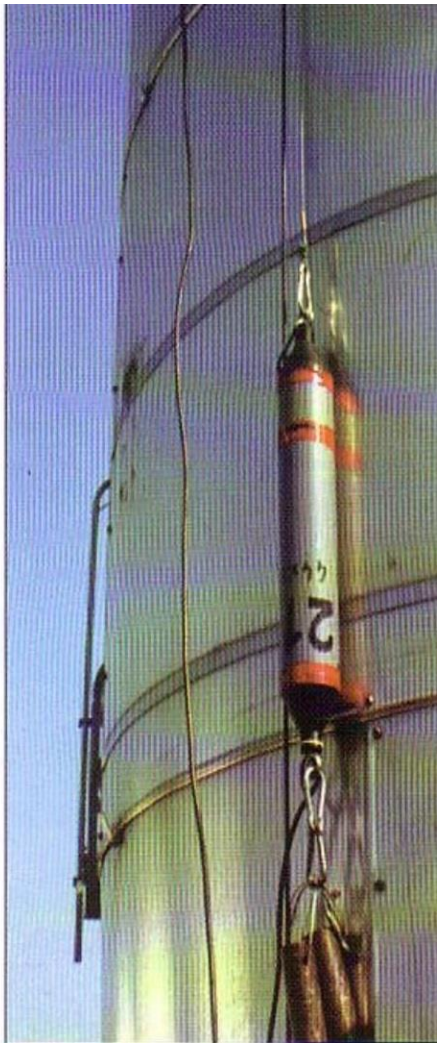
Gamma scanning

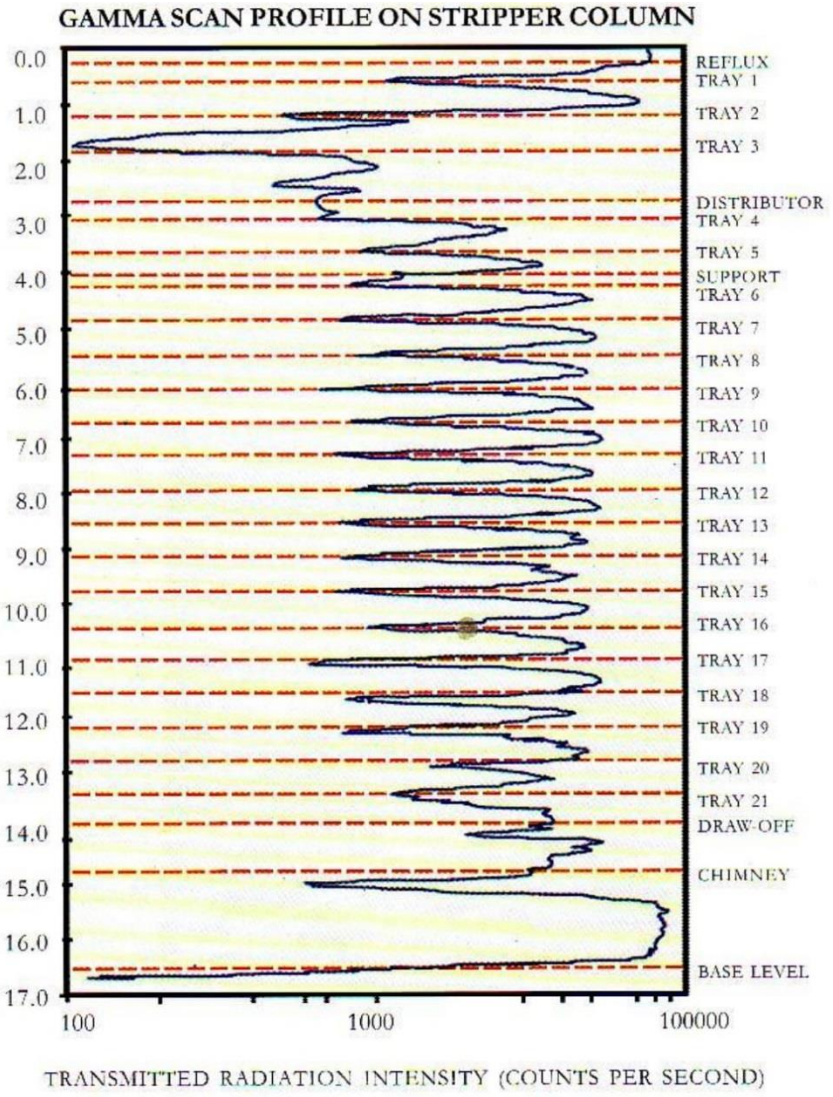
Typical gamma scan profiles in trayed (left) and packed bad (right) columns



Gamma scanning inspection



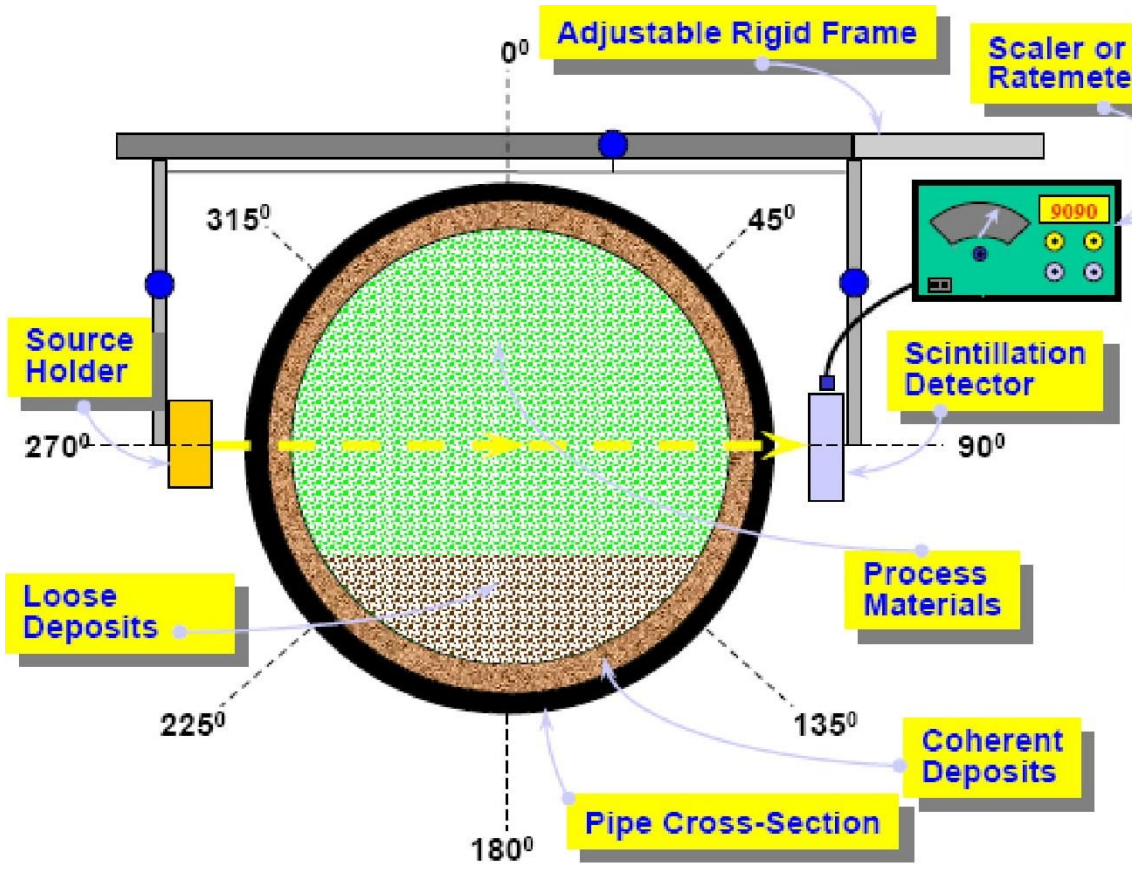




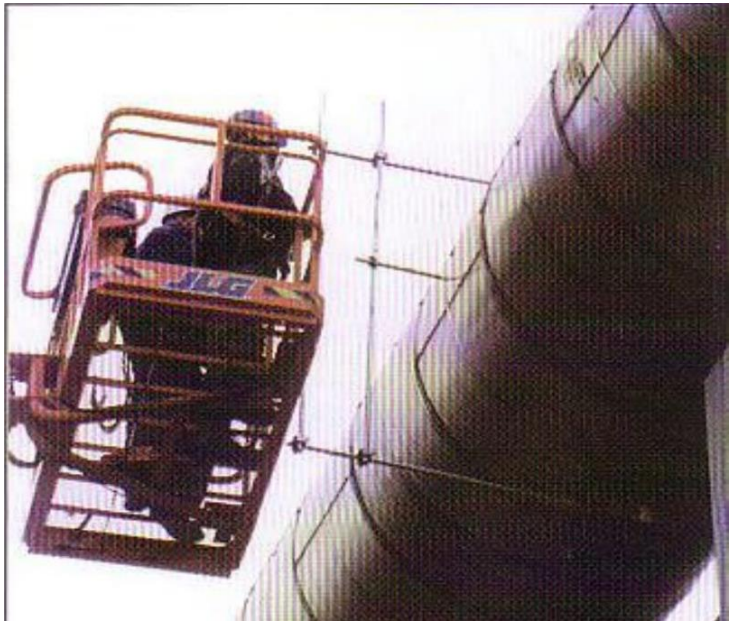
Pipe scanning

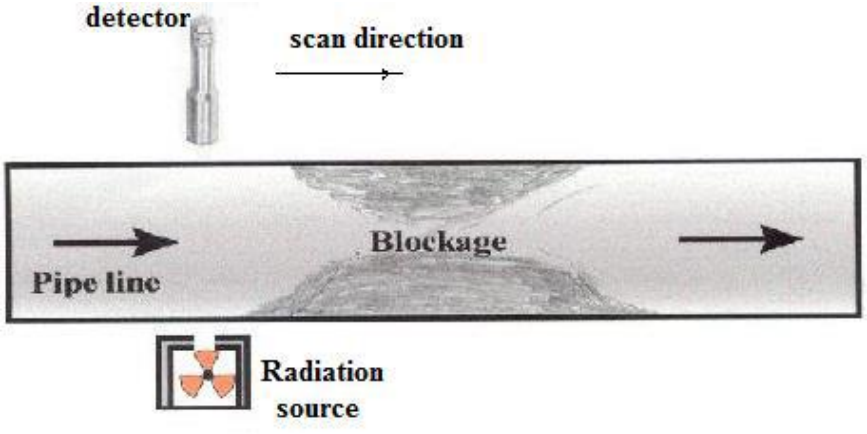
By applying gamma scanning technique to piping, can quickly:

- Locate blockages
- Locate scale or coke build-up
- Locate liquid in vapour lines
- Locate areas of lost refractory or lining in a pipe
- Measure flowing densities
- Evaluate the fluidizations of catalyst



Gamma pipe scanning

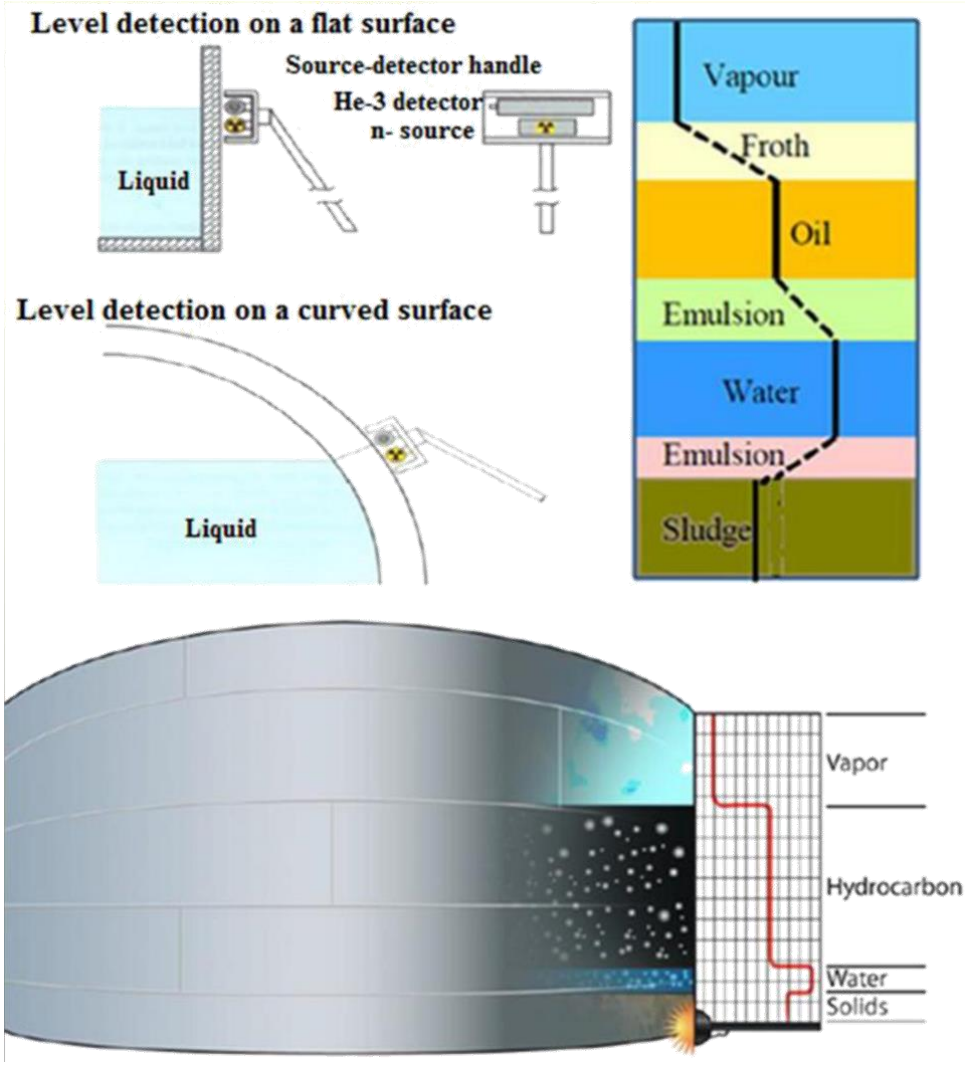




Principle of neutron backscattering technique

Neutron energy transferred to a target nucleus on collision is:
$f = 1\text{-}e^{-k}$
k = constant

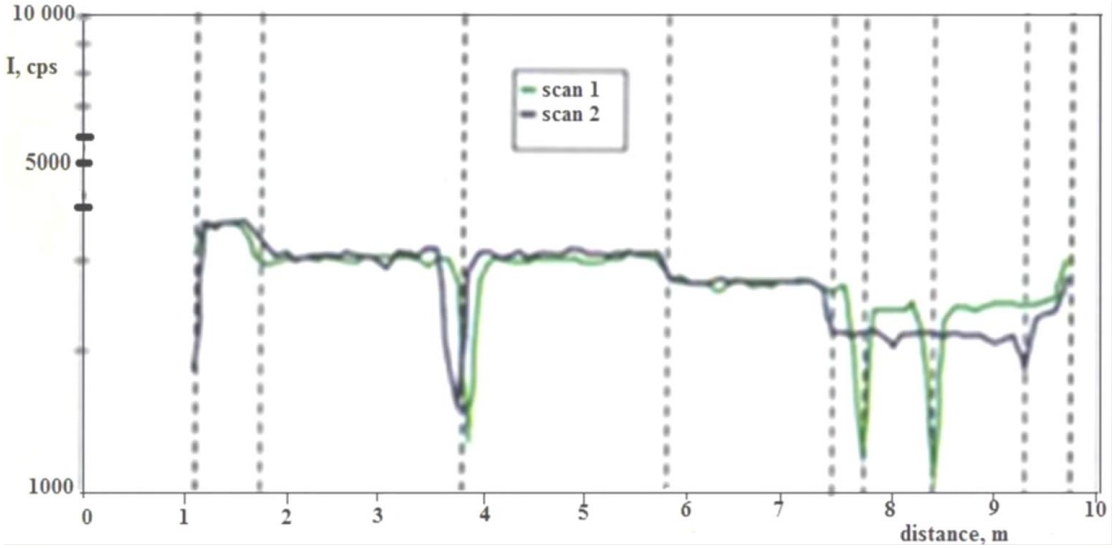
For hydrogen: k = 1, mean energy transfer during a collision with fast neutrons is 63% of energy of neutron, for carbon: k = 0.159, it is 14.7%.



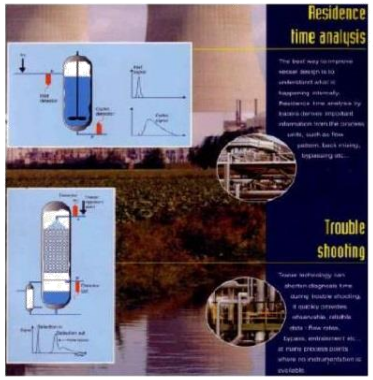
Interface level measurement in a crude tar tank

Scan profile shows four hydrogen content liquids.

Four layers of hydrocarbon fractions were separated during storage.



Radiotracer and sealed applications in industry



Cost-benefits ratio1:30

Radiotracer and sealed source techniques:

- Enhance quality, productivity, reliability and safety
- Improve efficiency
- Reduce production down-time
- Make worker's performance easier
- Reduce industrial pollution
- Save money

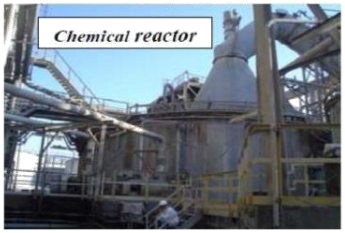

Minerals processing


FCCU


Flow rate measurement

Hydraulic detention times in wastewater treatment ponds


Leak detection in heat exchanger

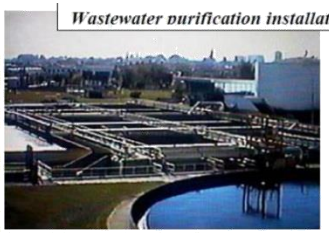

Chemical reactor

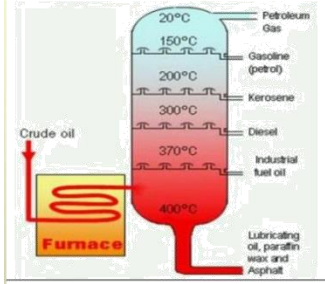
Some examples of nucleonic measurement and control systems


Paper Thickness | Mineral Industry | Coating

Radiotracer and gamma scanning

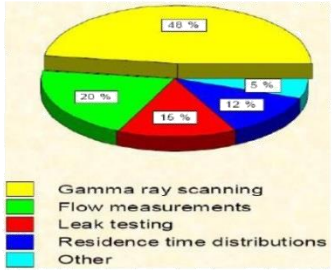
Wastewater purification installations

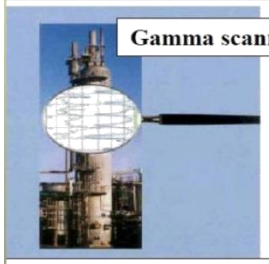




Fractional distillation column in oil refinery

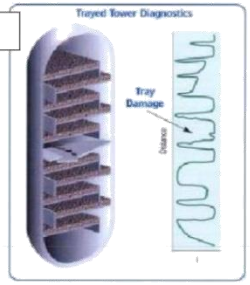
>10 000 services per year, out of them >5000 gamma scanning





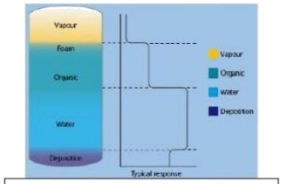
Gamma scanning

Benefits for one column inspection
US$ 100000



Pipe scanning for corrosion

Level inspection in Oil storage tanks



Neutron backscattering gauge

Oil separator investigation

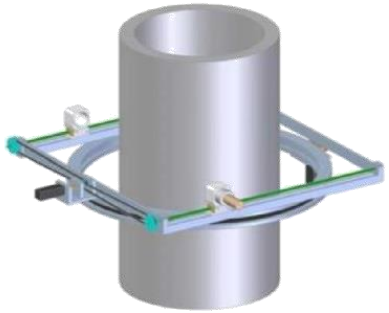
Petrochemical complexes

Petroleum industry

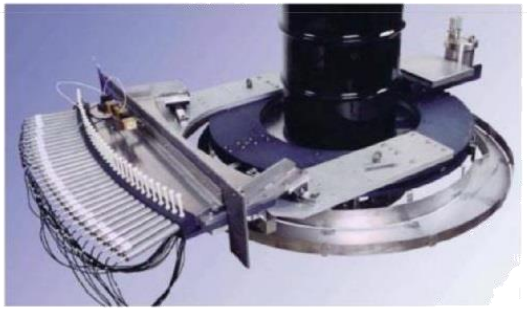
Radiation Protection Inspector

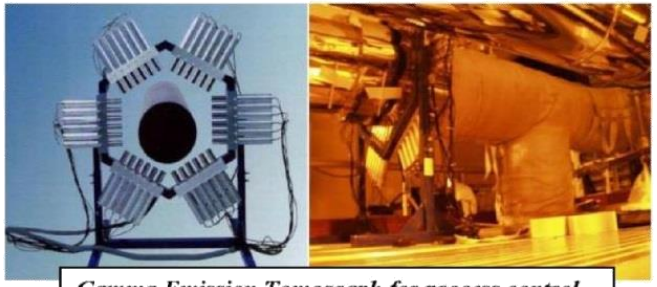
Truck inspection

Portable gamma CT for wood pole inspection



Gamma TransmissionTomographs (IS-1D and IS-MD) for material and process inspection





Gamma Emission Tomograph for process control

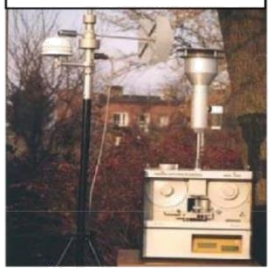
Contribution of nucleonic gauges to the industry and environment worldwide is estimated to some billion US$ per year.

Looking at the trends in the industrialization process of the countries, there is evidence that NCS and radiotracer technology will continue to play an important role in industry for many years to come.

NCS for paper, glass and plastic

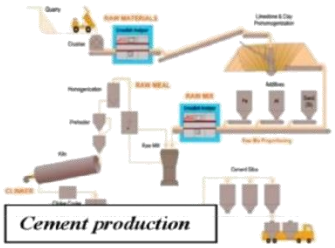
Installing a density gauge for sugar

Monitoring airborne dust



More than 250 000 Nucleonic Gauges in operation worldwide are:

- saving raw materials,
- almost instantaneous monitoring quality of manufactured product,
- reducing labour cost,
- reducing waste and rejects,
- fighting contraband and terrorism.



Cement production

Searching for coal

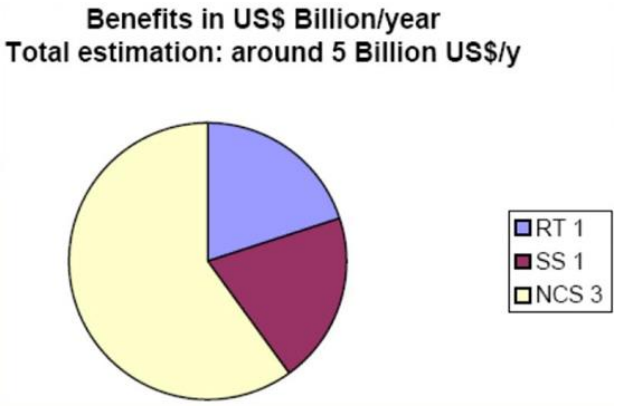
Controlling coal ash

Online coal ash and mineral slurry analyzers installed around the world increase productivity valued at some hundred M US$ per year. The pays-back is 3-9 months following installation.

Searching for minerals and coal

Monitoring quality of mineral ore

BENEFITS and PERSPECTIVE



We should not let unjustified fear of radiation create obstacles to continued progress and benefits.

We should make the public more aware!

Safety guidelines are important!

1. Flow rate measurements are important applications, they are used for calibration of conventional flow meters, for accurate flow rate distribution balance and for troubleshooting processing units.
2. Leak detection is largely used in heat exchangers and underground pipelines.
3. Radiotracer RTD method is largely used in routine service to all processing industries for troubleshooting and diagnosing purposes.
4. Gamma scanning technique is largely used in petrochemical industry for column troubleshooting and diagnosing.

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